REMARKS

Claims 1-3, and 5-37 are pending in the application. Claims 1 and 3 have been amended and claim 4 has been cancelled. Further, claims 36 and 37 are newly added to the application. No new matter has been introduced by the amendment.

Rejection Under 35 U.S.C. §102(b) or 35 U.S.C. §103(a)

Claims 1-3, 7-9, 19 and 34 have been rejected over U.S. Pat. No. 5,129,827 to Hoshi et al. This rejection is overcome in view of the amendment of claim 1, together with the following remarks.

Claim 1, as amended, recites a method of producing a complex structure in which mechanical forces are applied to each of two structures before bringing them together. The mechanical force curves the structures so that their connecting faces are respectively concave and convex when bringing them into contact so as to create a tangential stress state difference between the two structures. The tangential stress state difference creates a predetermined stress state.

An embodiment of the claimed configuration is describe in the applicants' specification, in which a first structure is deformed to have a spherical concave shape and a second structure is deformed to have a spherical convex shape. The assembled face of the first structure is spherical concave, and is therefore in compression. Correspondingly, the assembled face of the second structure is spherical convex, and is therefore under tension. (Specification, pg. 15, ll. 18-28, and FIG. 6A). The arrows in FIG. 6A of the applicants' drawing represent the tangential internal stresses within the complex structure, where compression force is shown by arrows directed toward each other, while tensile force is shown by arrows directed away from each other. As set forth throughout the applicants' specification, the inventive method achieves numerous advantages over the prior art. For example, the complex structure so formed compensates stresses generated during subsequent technology steps and, in particular, reproducibly enables technology steps involving greater temperature differences or of longer duration than could be achieved by the prior art. (Specification, pg. 3, ll. 6-13).

The significance of the stress state resulting from the tangential stress state difference during assembling, after removal of the curvature forces, and during possible later steps, is disclosed in the applicants' specification, for example, on page 21, beginning at line 20 and is illustrated in FIGs. 6A to 6D and 9A to 9F of the applicants' drawing.

In contrast to the applicants' claimed method, Hoshi et al. disclose a method for bonding semiconductor substrates that involves warping a semiconductor wafer, bringing the warped semiconductor wafer into contact with another semiconductor wafer at one contact point. The pressure is reduced in the atmosphere surrounding the semiconductor wafers to flatten the warped semiconductor wafer. (See Abstract). Hoshi et al. teach that an object of the disclosed process is to provide a method for bonding semiconductor substrates in which a solid bonded wafer can be manufactured without leaving air bubbles in the bonded wafer. (Col. 1, ll. 40-57). For that purpose, at least one of the wafers is warped so that it can contact the other wafer at only one contact point. When contact at the point is made, the warped wafer is released to its original shape so that the contact area with the other wafer is progressively increased.

None of the several embodiments disclosed by Hoshi et al. suggest or disclose the applicants' claimed method. As shown in FIGs. 3A to 3F, both wafers are stressed so as to be concave (FIG. 3B). The convex faces are brought into contact in a contact area (FIG. 3D), and are then released (figure 3E). Thus, Hoshi et al. discloses a process in which the wafers are pre-stressed by warping so as to form a contact point, and the stress is released by complete contact. There is no tangential stress difference when both wafers are fully brought into contact with each other; thus there is no predetermined stress state when the stress is released. It is important to note that, when two wafers are oppositely curved, as disclosed by Hoshi et al., and the oppositely curved faces are brought into contact, when the wafers are allowed to return to their plan configuration, the stress in both wafers is released, and there is no tangential stress difference between the assembled wafers.

The remaining embodiments disclosed Hoshi et al. are similar to the embodiment discussed above, except that either one of the wafers is pre-stressed by warping, or both wafers are warped as in the first embodiment, with an intermediate wafer inserted between them. In another embodiment, both wafers are warped as in the first embodiment and the contact point is near the periphery instead of at the middle. Accordingly, Hoshi et al. do not suggest or disclose curving two structures so that their connecting faces are respectively concave and convex when bringing them into contact so as to create a tangential stress state difference between the two structures.

Claims 2-3, 7-9, 17, 19, and 34 depend directly or indirectly from claim 1. Claim 3 has been amended to maintain proper antecedent basis with claim 1, and claim 5 has been amended in view of the cancellation of claim 4. These claims are allowable in view of the amendment and remarks pertaining to claim 1.

Rejection Under 35 U.S.C. 35 U.S.C. §103(a)

Claims 1-3, 7-9, 19, 23, 34, and 35 have been rejected over Hoshi et al. in view of the article entitled "Prestressing of Bonded Wafers" by Feijoo et al. This rejection is overcome in view of the amendment of claim 1, together with the following remarks.

The applicants' foregoing remarks pertaining to Hoshi et al. are incorporated herein. The applicants assert that the addition of Feijoo et al. does not overcome the deficiency of Hoshi et al. The Feijoo et al. reference is described in the Background section of the applicants' specification, beginning at page 3, line 27, and continuing to line 12 of page 5. To the extent that Feijoo et al. disclose a structure in which the faces are respectively concave and convex, as described in the applicants' specification, these wafer shapes result from a deformation caused after assembling of both of the wafers. (Specification, pg. 4, ll. 4-20). In contrast to Feijoo et al., the applicants claim a method in which mechanical force is applied before bringing the two structures into contact. Further, the applicants point out the numerous disadvantages associated with the method disclosed by Feijoo et al. (Specification, pg. 4, ll. 20-35, pg.,5, ll. 1-12).

Accordingly, the applicants assert the combination of Hoshi et al. with Feijoo et al. would not suggest their claimed method to one skilled in the art.

Claims 2-3, 7-9, 19, 23, 34, and 35 depend directly or indirectly from claim 1. These claims are allowable in view of the amendment and remarks pertaining to claim 1.

In particular, claim 19 recites that the face of at least one of the two structures is adapted to prevent air from being trapped between the connecting faces. The problem of minimizing trapped air bubbles is treated, according to the invention, in a different way than by Hoshi et al. As disclosed at page 13 of the applicants' specification, the contact between the wafers may be made immediately on the whole surface.

Regarding claim 23, the Examiner has questioned the meaning of the term "flow layer." (Office Action, pg. 4-5). The applicants assert that this term is described in their specification at page 24, under the heading "Flow Layer." The applicants assert that one skilled in the art will understand claim 23 after reading the applicants' specification. The applicants further assert that although Hoshi et al. disclose an intermediate wafer, there is no suggestion by Hoshi et al. that the intermediate wafer have flow properties.

Claim 35 depends from claim 1 and is directed to the use of hydrogen. Regarding claim 35, the Examiner has asserted that an inert gas is conventional. (Office Action, pg. 5). The applicants disclose the use of hydrogen to facilitate molecular bonding in their inventive process. (Specification, pg. 6, ll. 34-35, pg. 7, ll. 1-10). The applicants assert that the cited references do not suggest or disclose the use of hydrogen in an assembly process.

Claims 4-6, 10-12 29 and 30 have been rejected over the Hoshi et al and Feijoo et al., further taken with U.S. Pat. No. 5,071,785 to Nakazato et al. This rejection is overcome in view of the amendment of claim 1, together with the following remarks.

The rejection of claim 4 is now moot in view of the cancellation of claim 4, however, the subject matter of claim 4 has been introduced in claim 1. Accordingly, the reasons set forth herein, the applicants assert that claim 1 is allowable over the cited combination of references.

The applicants' foregoing remarks pertaining to Hoshi et al and Feijoo et al. are incorporated herein. The applicants assert that the addition of Nakazato et al. does not overcome the deficiency of Hoshi et al. and Feijoo et al.

Nakazato et al. disclose a method for preparing a substrate for forming semiconductor devices by bonding warped wafers. The method provides a substrate of remarkably less warp. (Col. 1, ll. 10). An SOI structure is provided that minimizes the warping obtained after bonding two plane silicon wafers that are fully covered with oxide. This is followed by etching or polishing one of the wafers so that, in particular, one of the wafers is no longer covered by oxide on its face opposite the bonded second wafer. (Col. 2 and FIGs. 4A to 4C). The warping under consideration is very small, since FIG. 5 shows depressions of far less than 100 microns, such as about 40 microns, and the wafers under consideration have a diameter of about 150mm. (Col. 5, ll. 11-49, Col. 6, ll. 35-40. Nakazato et al. is limited to the case where an oxide layer is sandwiched between the wafers, and an oxide layer is formed on the entire surface of the wafers, after the wafers are already warped. Nakazato et al. disclose that the warp to be compensated is caused by the oxide film 1c. (Col. 3, ll. 21-24). Accordingly, one skilled in the art would understand that the teaching of this reference is limited to the production of SOI structures with an oxide layer between the assembled wafers.

Further, Nakazato et al. do not disclose how to warp at least one of the wafers while forming an oxide layer on the "whole" surface of the warped layers. It is also not clear how to curve a wafer while leaving its entire surface available for the formation of an oxide layer. Accordingly, the applicants disagree with the characterization of Nakazato et al. at page 5 of the Office Action. The applicants assert that Nakazato et al. fail to provide any teaching as to how to warp two wafers, and fail to teach any application of mechanical forces so as to assemble a concave face to a convex face.

In contrast, the applicants' claimed invention deals with significant stresses in the two structures. For example, the applicants' specification describes an example of a deflection of 3 mm for a wafer of 200 mm diameter. (Specification, pg. 11, ll. 29-35, pg. 12, ll. 1-8). This is several tens higher than the deflection disclosed by Nakazato et al.

It is submitted that, when significant warping is produced before bringing the wafers into contact, assembling wafers in which one is concave and the other is convex must be made with care so as to provide a high quality bond over the entire surface of the assembly. Neither Hoshi et al nor Nakazato et al. suggest or disclose such a method since there is no practical teaching in Nakazato et al., and Hoshi et al. fail to teach or suggest any assembly of a concave surface to a convex surface. Moreover, Feijoo et al. do not disclose warping wafers prior to assembly. Accordingly, the combination of the cited references fails to suggest or disclose the method recited by claim 1.

The applicants further assert that since Hoshi et al. and Nakazato et al. have very different objects, one skilled in the art would not have any reason to combine these references. And, even if the cited references are combined, one skilled in the art would not reach the invention as defined in the claims.

Claims 5-6, 10-12 29 and 30 depend directly or indirectly from claim 1. These claims are allowable in view of the amendment and remarks pertaining to claim 1. Further, these dependent claims cover specific and detailed features that provide practical solutions for obtaining significant curvatures of both surfaces to be assembled that are neither taught nor suggested by the cited references.

Claims 13-16, 18 and 20-22 have been rejected over Hoshi et al. and Feijoo et al., further taken with U.S. Pat. No.5,478,782 to Satoh et al. This rejection is overcome in view of the amendment of claim 1, together with the following remarks.

The applicants' foregoing remarks pertaining to Hoshi et al and Feijoo et al. are incorporated herein. The applicants assert that the addition of Satoh et al. does not overcome the deficiency of Hoshi et al. and Feijoo et al.

Apparently, Satoh et al. is cited for their disclosure of a porous mold. (Office Action, pg. 6). Satoh et al. do not suggest or disclose a method of producing a complex structure in which mechanical force curves the structures so that their connecting faces are respectively concave and convex when bringing them into contact so as to create a tangential stress state difference between the two structures. Claim 13 recites that mechanical force of claim 1 is applied simultaneously to the two structures by deforming

the two structures between two preforms having selected profiles to be imparted to the connecting faces. Satoh et al. does not suggest or disclose the process recited by claim 13.

Similarly, the combination of cited references does not suggest or disclose the methods of claims 14-16, 18, and 20-22, which depend directly or indirectly from claim 1.

Claims 24-28 have been rejected over Hoshi et al. and Feijoo et al., further taken with Shimbo et al., or U.S. Pat. No. 4,939,101 to Black et al. This rejection is overcome in view of the amendment of claim 1, together with the following remarks.

The applicants' foregoing remarks pertaining to Hoshi et al., Feijoo et al. and Satoh et al. are incorporated herein. The applicants assert that the addition of Black et al. does not overcome the deficiency of the remaining cited references. Apparently, Satoh et al. and Black et al. are cited for their disclosure of a heat treatment. (Office Action, pg. 7). Claims 24-28 recite various aspects of the invention carried out at elevated temperatures. These claims relate to a particular advantage associated with the claimed method. As set for the by the applicants beginning at page 17 of their specification and continuing to page 20, the stress created is adjusted to compensate for elevated temperatures. In the case of a composite structure, for example, "[b]y an appropriate choice of the process of assembly under stress, it is also possible to minimize and even to eliminate stresses within a composite structure at a given temperature, for example the heat treatment temperature." (Specification, pg. 18, ll. 28-33). The applicants assert that the cited combination of references does not suggest the heat treatments recited by claims 24-28 in the method of claim 1.

In particular, claim 27 relates a method in which the assembly is made so as to generate a stress state that, at a different processing temperature, is converted to a low stress state due to possible difference of thermal expansion coefficients. (Specification pg. 7, line 32, to pg, 8 line 19). As described above, the method of claim 27 is of particular significance when the assembled structures have different coefficients of thermal expansion. Accordingly, the assembly under stress may, at some other

temperature, experience no significant stress so that a processing step at that temperature is very efficient . (See FIGs. 7A and 7B and the associated description).

Claims 31-33 have been rejected over the Hoshi et al. and Feijoo et al., further taken with U.S. Pat. No.4,830,984 to Purdes. This rejection is overcome in view of the amendment of claim 1, together with the following remarks.

The applicants' foregoing remarks pertaining to Hoshi et al. and Feijoo et al. are incorporated herein. The applicants assert that the addition of Purdes does not overcome the deficiency of Hoshi et al. and Feijoo et al.

Purdes is apparently cited for its disclosure of the formation of a layer on a substrate that creates a compensating tensile stress. (Office Action, pg. 7-8). Claims 31-33 address further advantages aspects of the method recited in claim 1. These claims relate to a case where after removal of the mechanical forces, the stress state generates a change of lattice dimension. Accordingly, an epitaxial process can be carried out. Correspondingly, the unstressed material has a lattice dimension which is not appropriate for epitaxy. (Specification pg. 20-23). By iteration of the assembly, it is possible to obtain lattice parameters quite different from the unstressed parameter of the assembled structures. The applicants assert that Purdes in combination with the remaining references does not suggest or disclose the method recited by claim 1, nor the tangential stress interplay with epitaxial growth recited by claims 31-33.

Double Patenting Rejection

The pending claims have been provisionally rejected over the Assignee's co-pending patent application having U.S. application serial no. 10/538,482. The applicants will file a Terminal Disclaimer to address this rejection at such time as there is an indication of allowable subject matter in the instant application.

New Claims

Claims 36 and 37 are newly added so that the applicants can more fully claim the subject matter of their invention.

Claim 36 recites a method similar to claim 1, with the additional step of removing mechanical forces. The removal of the mechanical forces is described, for example, at page 15 of the applicants' specification.

Claim 37 recites method of producing a complex structure wherein respective connecting faces of two structures having different coefficients of thermal expansion or different lattice constants, or both, are brought into contact and assembled. Mechanical forces are applied to each of the two structures before bringing them into contact to curve the two structures and to create a tangential stress state difference. The tangential stress state difference causes a predetermined stress state within the complex structure that is configured to provide a surface having a predetermined lattice parameter under subsequent processing conditions relative to the assembly conditions.

The processing of structures having different coefficients of thermal expansion or different lattice constants is described throughout the applicants' specification. See for example, pages 17-23.

The applicants assert that the methods recited by claims 36 and 37 are not suggested or disclosed by the cited references taken alone or in combination.

The applicants have made a novel and non-obvious contribution to the art of complex structure fabrication methods. The claims at issue are believed to distinguish over the cited references and to be in condition for allowance. Accordingly, such allowance is now earnestly requested.

Respectfully submitted,

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